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Murauchi et al.

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(54) **DEVELOPING DEVICE AND IMAGE FORMING APPARATUS**

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G03G 15/08 (2006.01)

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(58) **Field of Classification Search** 399/257, 399/30, 53, 62, 258
See application file for complete search history.

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(74) *Attorney, Agent, or Firm*—Buchanan Ingersoll & Rooney PC

(57) **ABSTRACT**

A developing device has stirring members for conveying and stirring a developer-tank-contained developer and a developer holder, and has a developer replenishing tank for replenishing a replenishment developer to a developer tank; a toner concentration detecting sensor; a discharging mechanism for discharging an excessive amount of the developer-tank-contained developer outside the developer tank when the amount of the developer-tank-contained developer inside the developer tank exceeds a predetermined amount; and a control unit for replenishing the developer-tank-contained developer when it is detected that the toner concentration inside the developer tank is lower than a first reference value and for forcibly consuming the toner inside the developer tank and replenishing the replenishment developer when it is detected that the toner concentration inside the developer tank is higher than a second reference value that is higher than the first reference value.

20 Claims, 7 Drawing Sheets

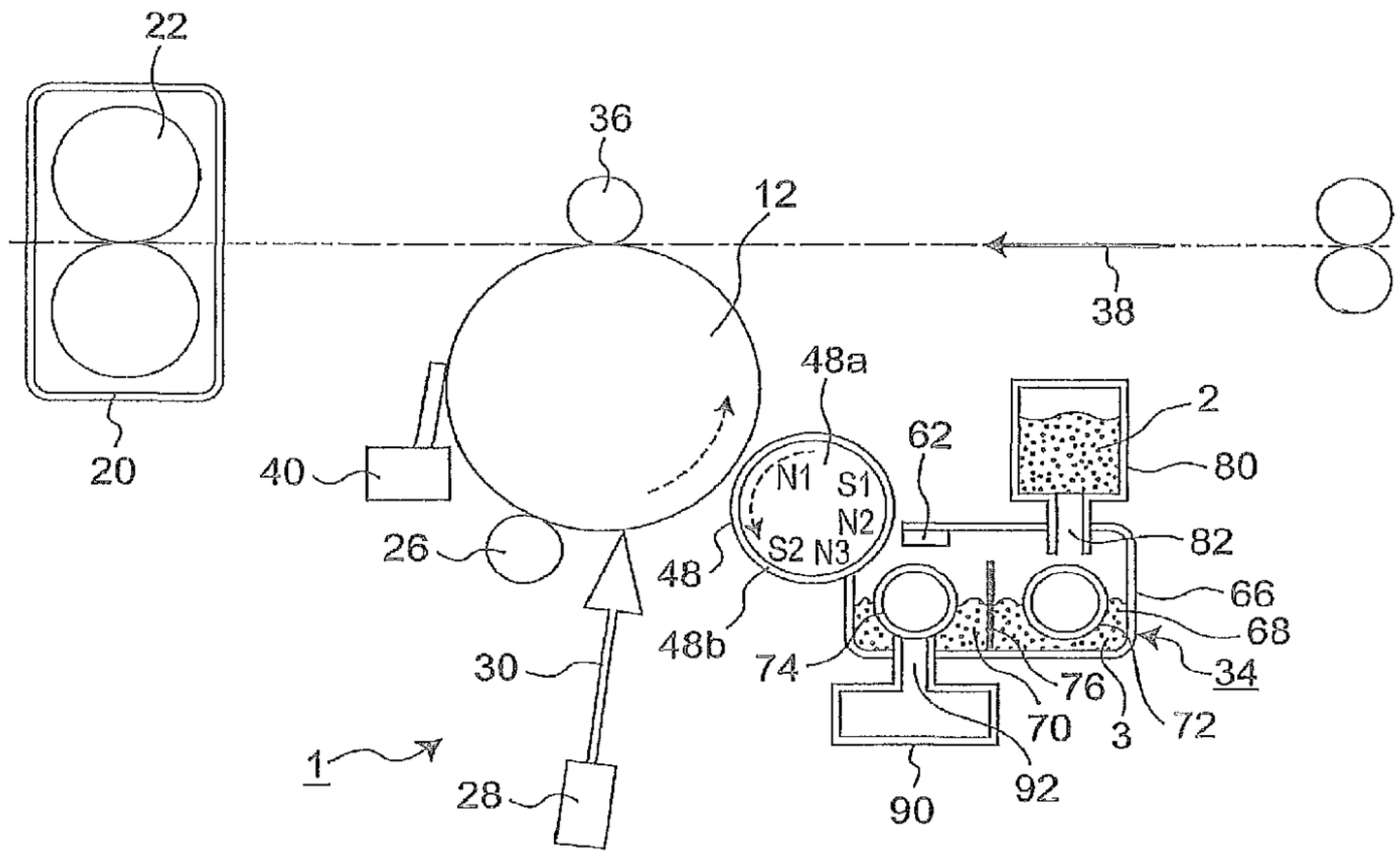
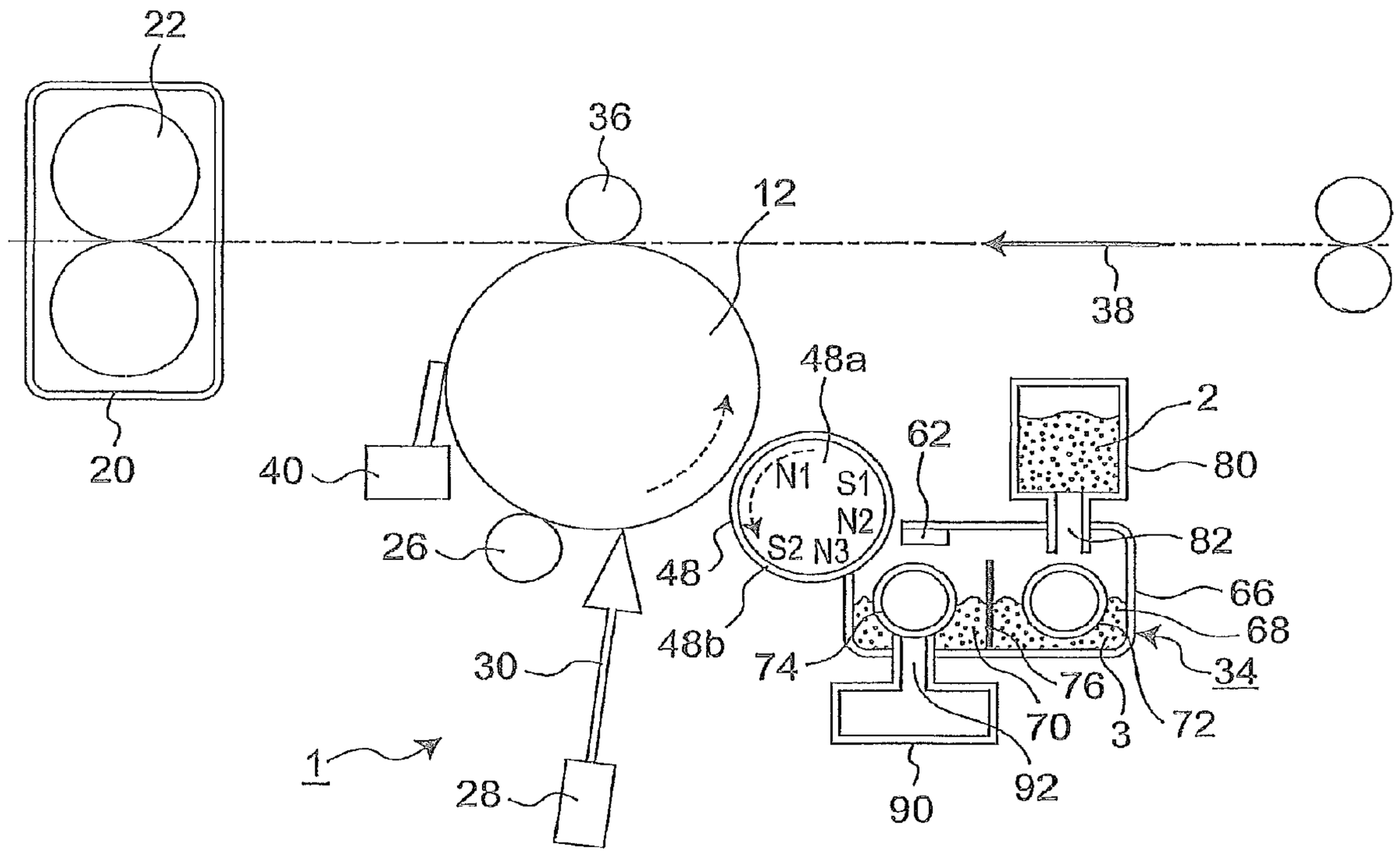


Fig. 1


22
36
12
38
20
40
48a
N1
S1
N2
S2
N3
62
2
80
82
66
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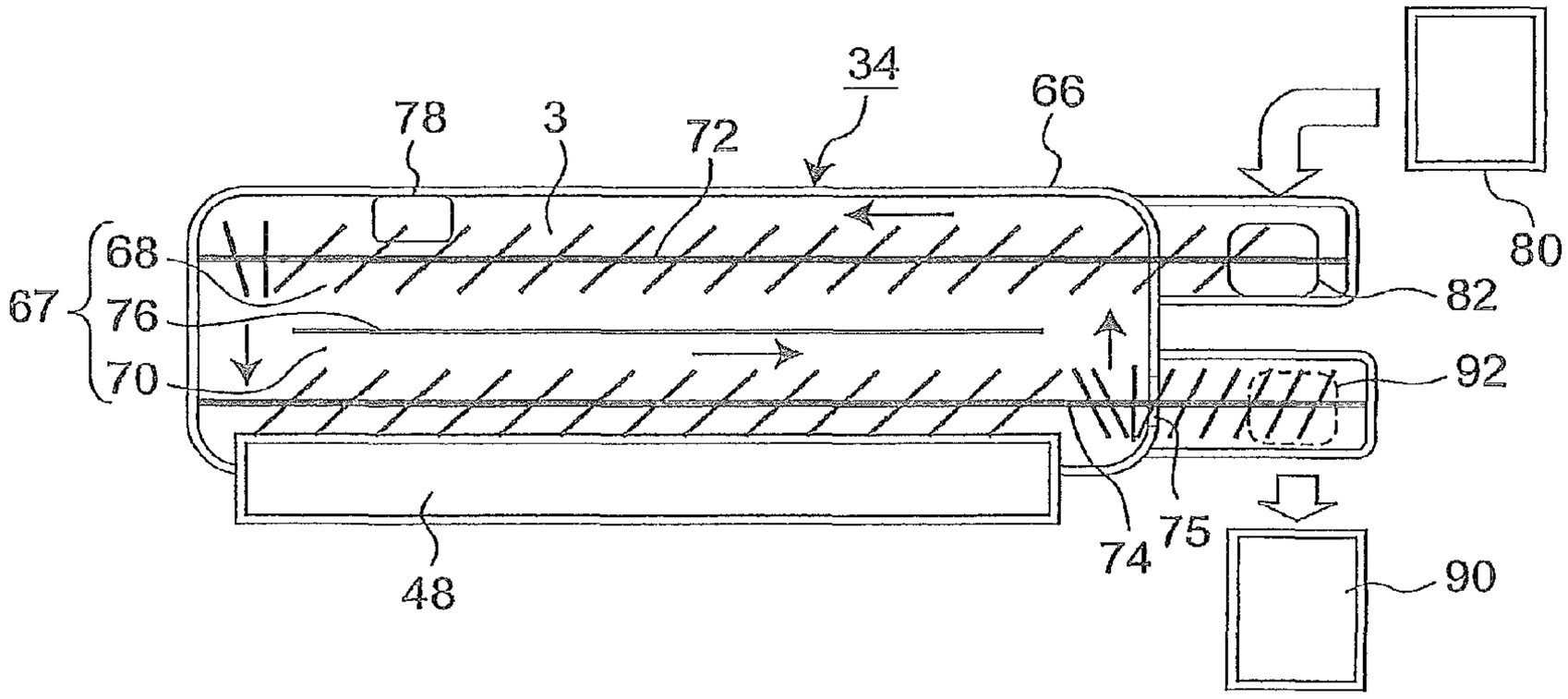
34
26
48
48b
74
76
70
3
72
30
1
28
90
92

Fig. 2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78
3
72
66
80
68
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74
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48
90

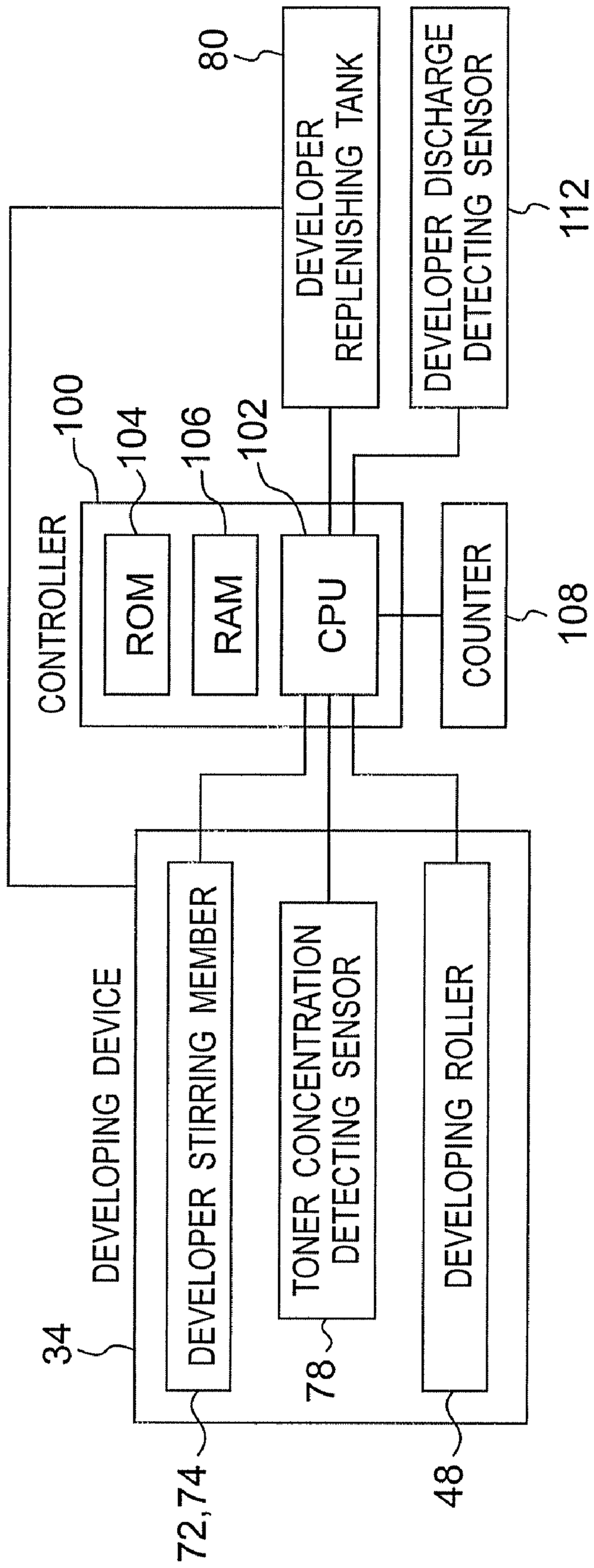

80
DEVELOPER REPLENISHING TANK
DEVELOPER DISCHARGE DETECTING SENSOR
112
100
104
106
102
CONTROLLER
ROM
RAM
CPU
COUNTER
108
DEVELOPING DEVICE
DEVELOPER STIRRING MEMBER
TONER CONCENTRATION DETECTING SENSOR
DEVELOPING ROLLER
34
72,74
78
48

Fig.3

Fig.4

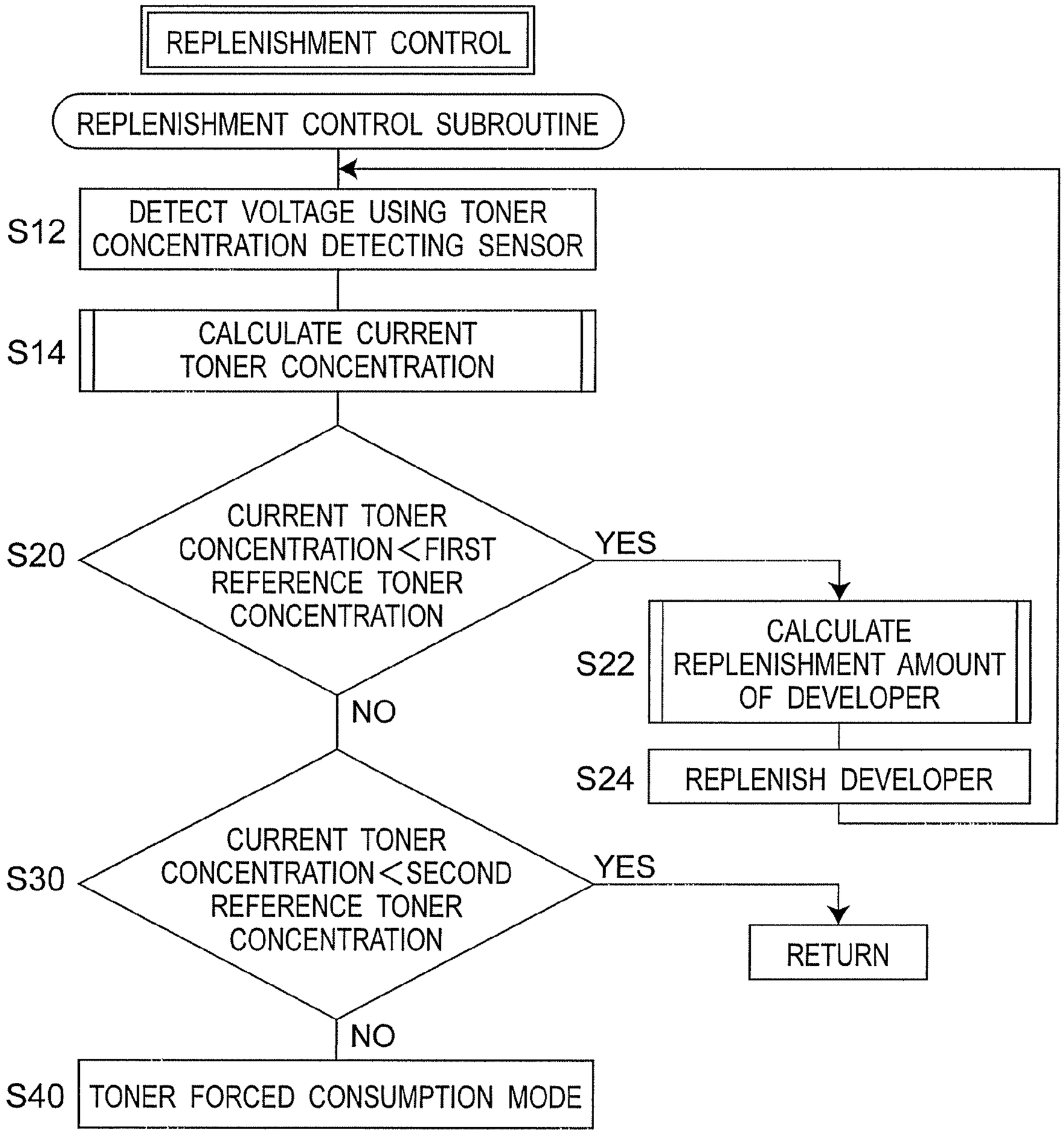

REPLENISHMENT CONTROL
REPLENISHMENT CONTROL SUBROUTINE
S12
DETECT VOLTAGE USING TONER CONCENTRATION DETECTING SENSOR
S14
CALCULATE CURRENT TONER CONCENTRATION
S20
CURRENT TONER CONCENTRATION < FIRST REFERENCE TONER CONCENTRATION
YES
S22
CALCULATE REPLENISHMENT AMOUNT OF DEVELOPER
S24
REPLENISH DEVELOPER
NO
S30
CURRENT TONER CONCENTRATION < SECOND REFERENCE TONER CONCENTRATION
YES
RETURN
NO
S40
TONER FORCED CONSUMPTION MODE

Fig.5

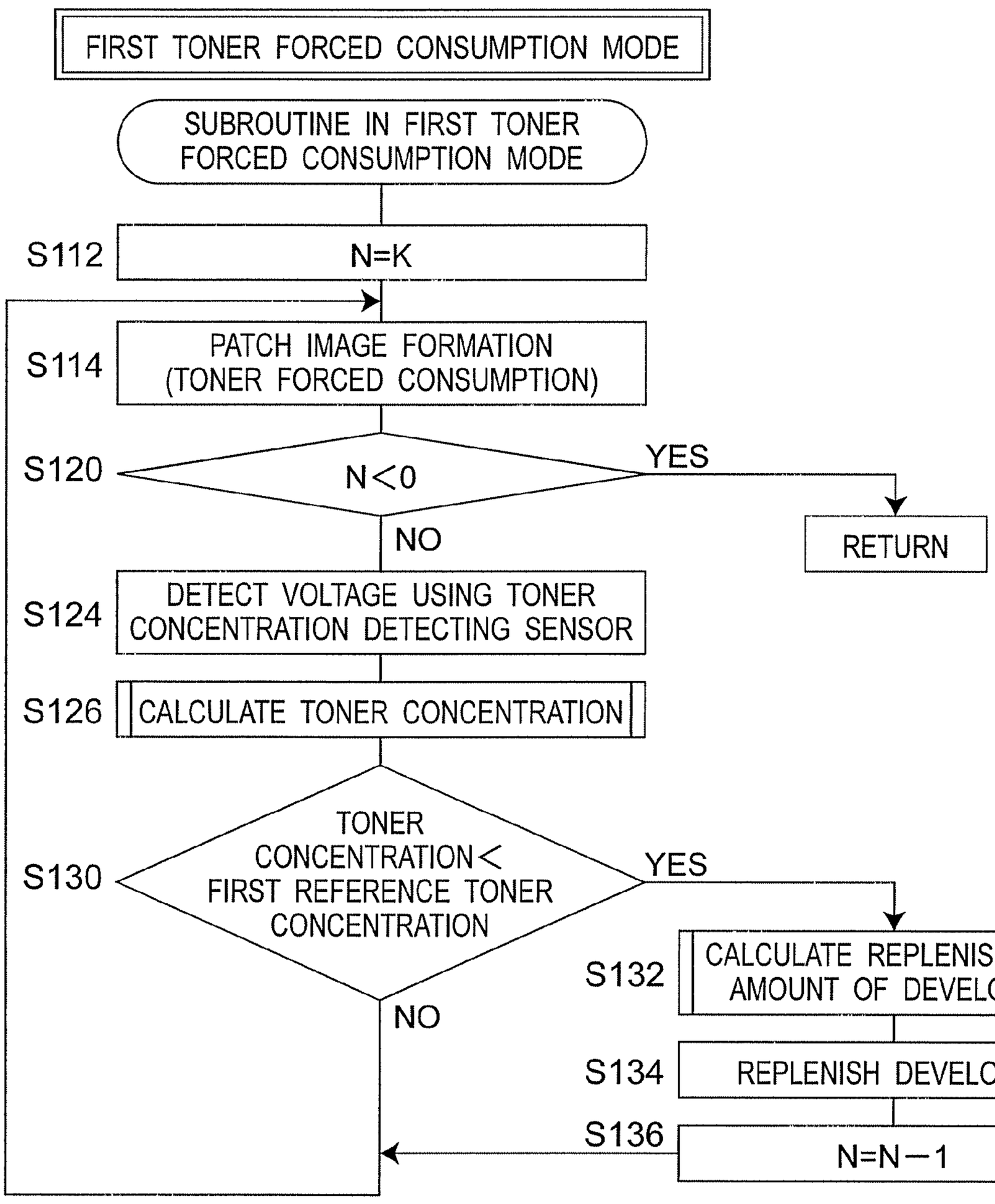

FIRST TONER FORCED CONSUMPTION MODE
SUBROUTINE IN FIRST TONER FORCED CONSUMPTION MODE
S112
N=K
S114
PATCH IMAGE FORMATION (TONER FORCED CONSUMPTION)
S120
N<0
YES
RETURN
NO
S124
DETECT VOLTAGE USING TONER CONCENTRATION DETECTING SENSOR
S126
CALCULATE TONER CONCENTRATION
S130
TONER CONCENTRATION < FIRST REFERENCE TONER CONCENTRATION
YES
S132
CALCULATE REPLENISHMENT AMOUNT OF DEVELOPER
S134
REPLENISH DEVELOPER
S136
N=N−1
NO

Fig.6

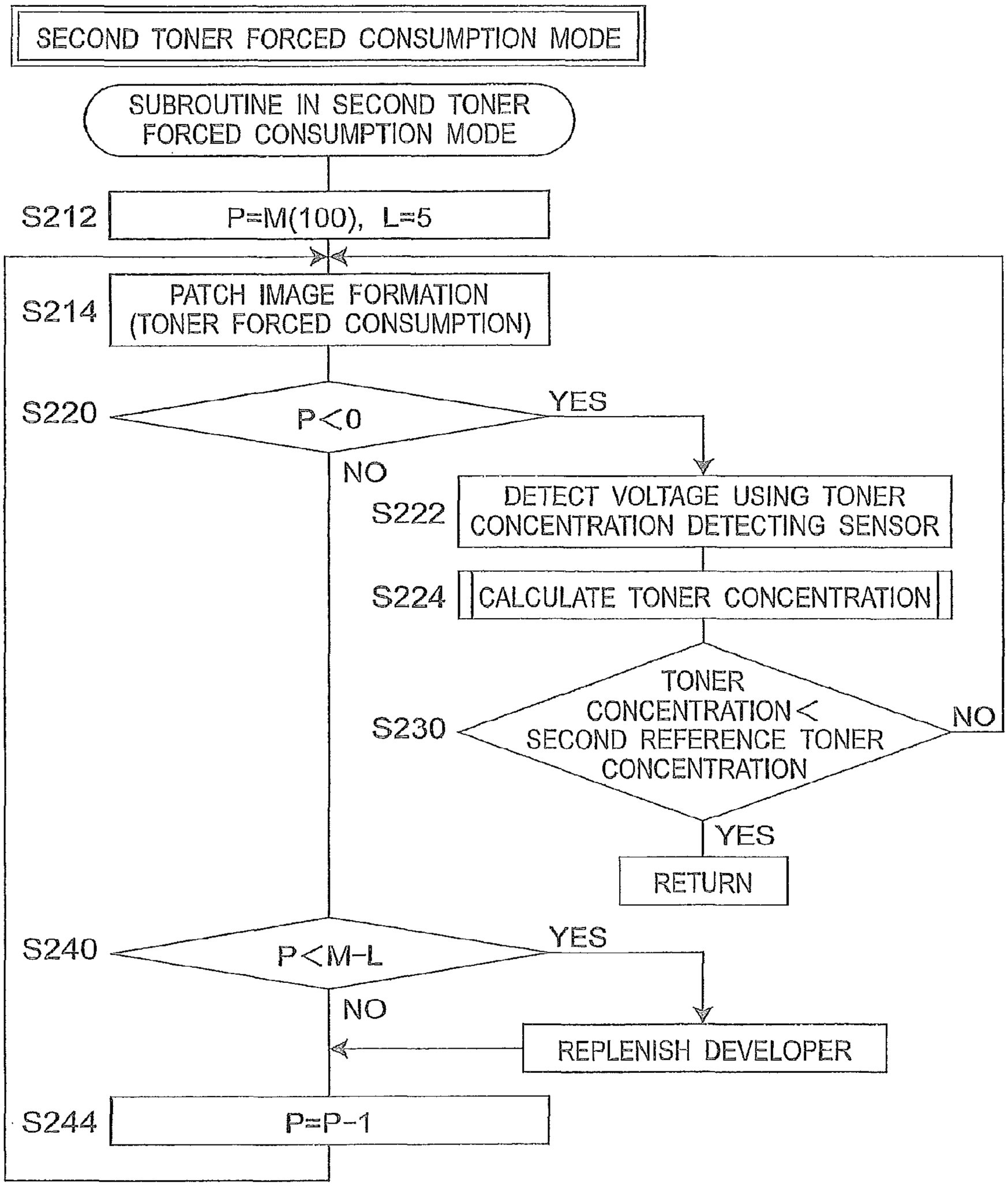

SECOND TONER FORCED CONSUMPTION MODE
SUBROUTINE IN SECOND TONER FORCED CONSUMPTION MODE
S212
P=M(100), L=5
S214
PATCH IMAGE FORMATION (TONER FORCED CONSUMPTION)
S220
P<0
YES
NO
S222
DETECT VOLTAGE USING TONER CONCENTRATION DETECTING SENSOR
S224
CALCULATE TONER CONCENTRATION
S230
TONER CONCENTRATION < SECOND REFERENCE TONER CONCENTRATION
NO
YES
RETURN
S240
P<M-L
YES
NO
REPLENISH DEVELOPER
S244
P=P-1

Fig.7

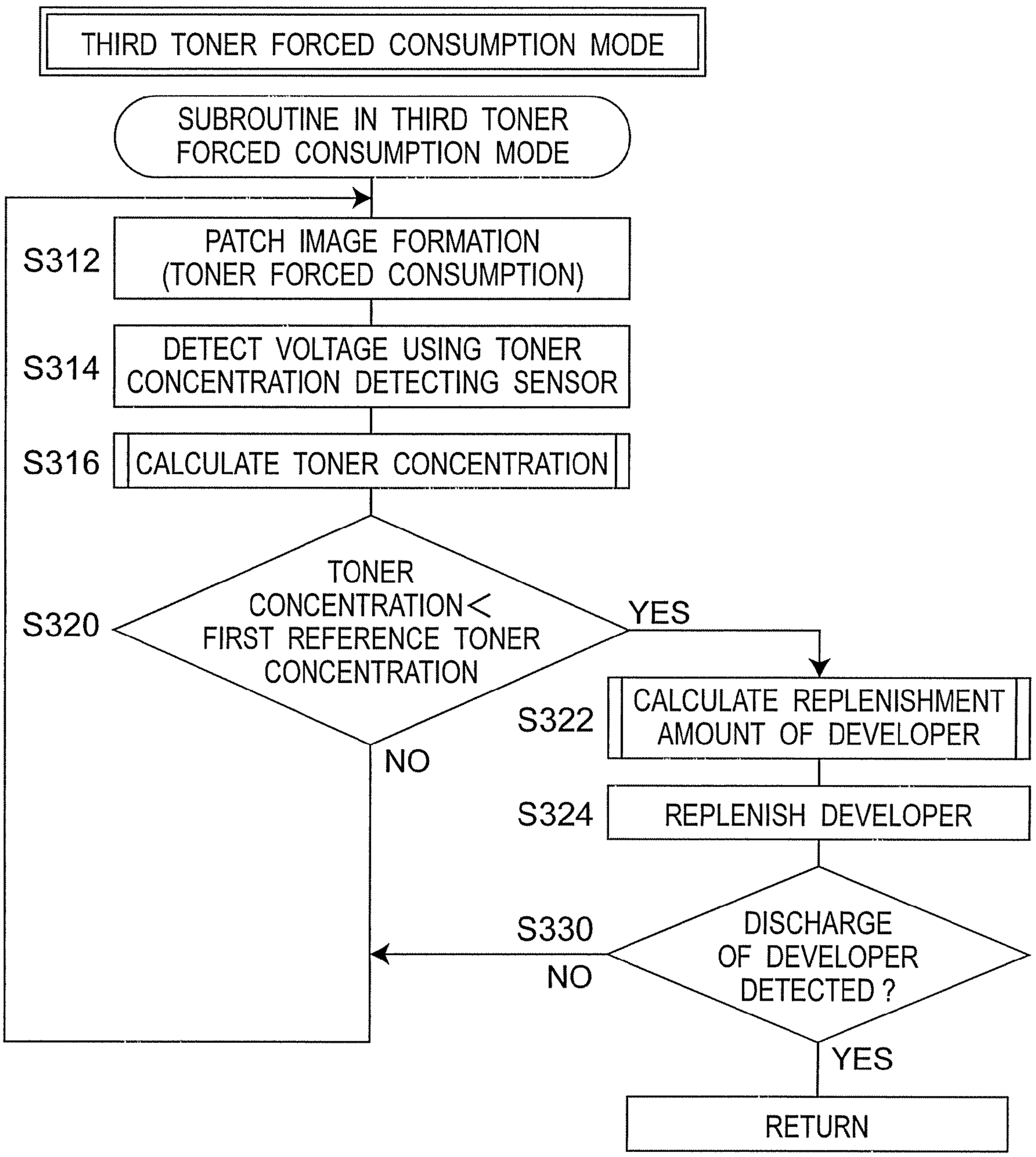
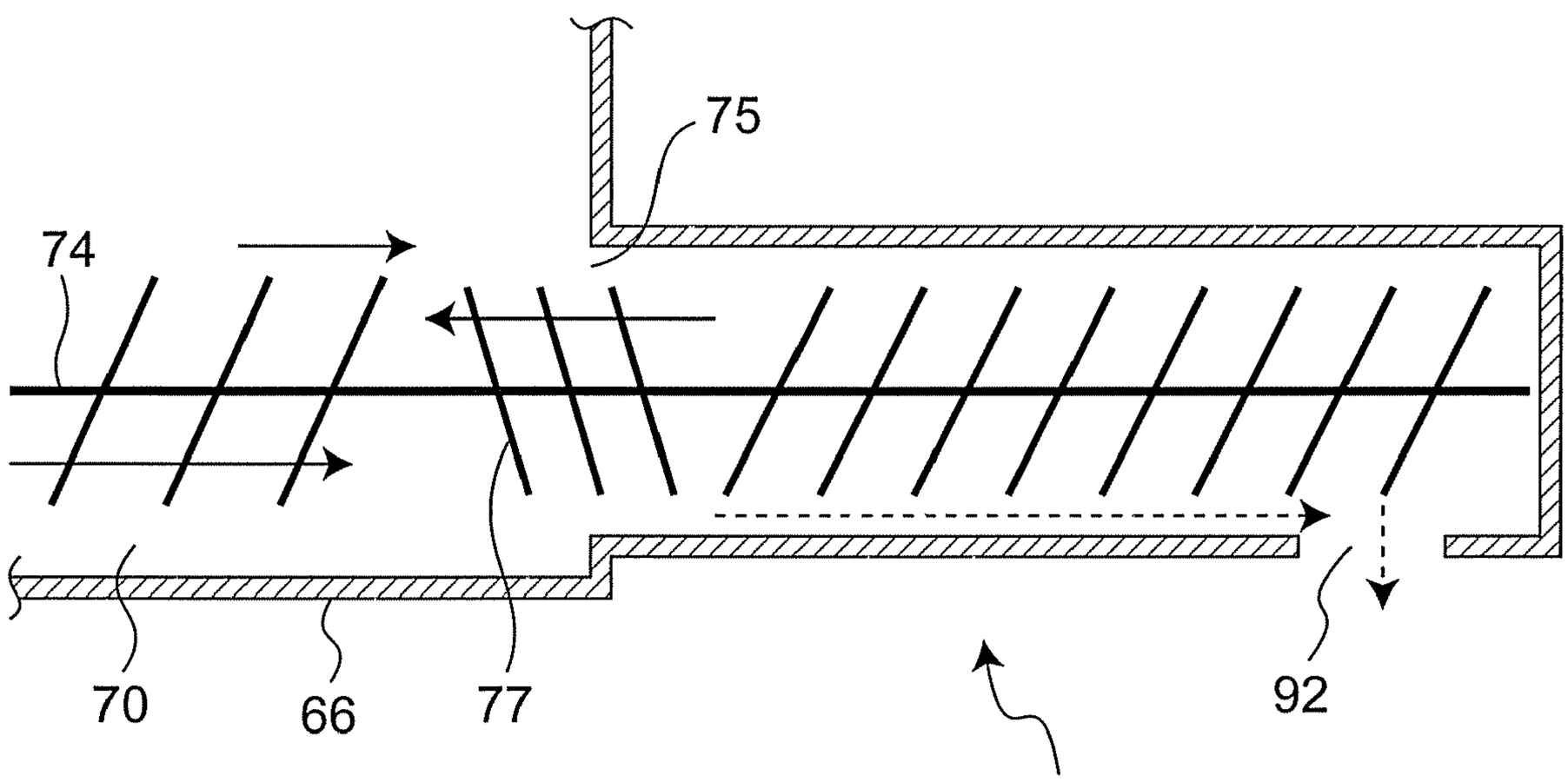

THIRD TONER FORCED CONSUMPTION MODE
SUBROUTINE IN THIRD TONER FORCED CONSUMPTION MODE
S312
PATCH IMAGE FORMATION (TONER FORCED CONSUMPTION)
S314
DETECT VOLTAGE USING TONER CONCENTRATION DETECTING SENSOR
S316
CALCULATE TONER CONCENTRATION
S320
TONER CONCENTRATION < FIRST REFERENCE TONER CONCENTRATION
YES
NO
S322
CALCULATE REPLENISHMENT AMOUNT OF DEVELOPER
S324
REPLENISH DEVELOPER
S330
DISCHARGE OF DEVELOPER DETECTED ?
NO
YES
RETURN

Fig.8



DEVELOPING DEVICE AND IMAGE FORMING APPARATUS

This application is based on applications No. 2007-222494 filed in Japan, the contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a developing device for use in an electrophotographic image forming apparatus and to an image forming apparatus incorporating the developing device. More particularly, the present invention relates to a trickle developing device that gradually supplies fresh developer and gradually discharge deteriorated developer and to an image forming apparatus incorporating the developing device.

2. Description of the Related Art

As developing systems employed for electrophotographic image forming apparatuses, the one-component developing system in which toner is used as the main component of the developer and the two-component developing system in which toner and carrier are used as the main components of the developer are known.

The two-component developing system that uses toner and carrier, in which the toner and carrier are charged by friction contact therebetween to predetermined polarities, has a characteristic that the stress on the toner is less than that in the one-component developing system that uses a one-component developer. Since the surface area of the carrier is larger than that of the toner, the carrier is less contaminated with the toner attached to the surface thereof. However, with the use for a long period, contamination (spent) attached to the surface of the carrier increases, whereby the capability of charging the toner is reduced gradually. As a result, problems of photographic fog and toner scattering occur. Although it is conceivable that the amount of the carrier stored in a two-component developing device is increased to extend the life of the developing device, this is undesirable because the developing device becomes larger in size.

To solve the problems encountered in the two-component developer, Patent document 1 discloses a trickle developing device being characterized in that fresh developer is gradually replenished into the developing device and developer deteriorated in charging capability is gradually discharged from the developing device, whereby the increase of the deteriorated carrier is suppressed. The developing device is configured to maintain the volume level of the developer inside the developing device approximately constant by discharging an excessive amount of deteriorated developer using the change in the volume of the developer. In the trickle developing device, the deteriorated carrier inside the developing device is gradually replaced with fresh carrier, and the charging performance of the carrier inside the developing device can be maintained approximately constant.

[Patent document 1] Japanese Patent Application Laid-Open Publication No. Sho 59-100471

However, since the volume of the developer inside the developing device changes depending on the concentration of toner and the deteriorated state of carrier, that is, the state of the developer inside the developing device, the ratio of the ingredients constituting the developer becomes different even if the volume of the developer remains the same.

The concentration of the toner inside the developing device is detected using, for example, a toner concentration detecting sensor that detects the permeability of the developer. For this reason, the measurement accuracy of the toner concentration detecting sensor is not sufficiently high, and the toner concentration indicated as a measured value may be different from the true toner concentration. In addition, the toner concentration obtained using the toner concentration detecting sensor may indicate a toner concentration different from the true toner concentration depending on the filling state of the developer around the toner concentration detecting sensor and the changes in the ambient environment of the image forming apparatus.

Because of various factors such as those described above, the toner concentration obtained using the toner concentration detecting sensor may be detected to be higher than a first reference toner concentration that is assumed to be appropriate. Since the trickle developing device is controlled such that the volume level of the developer inside the developing device is maintained approximately constant, if the toner concentration is detected to be high for some reason, the developer is not replenished for a while and ordinary image formation is carried out continuously until the toner concentration inside the developing device returns to the appropriate first reference toner concentration. When the toner concentration inside the developing device has returned to the reference toner concentration, the amount of the toner inside the developing device, that is, the amount of the developer, becomes scarce, and the volume level of the developer inside the developing device lowers. The fact that the volume level of the developer inside the developing device lowers indicates that the developer inside the developing device is insufficient. A stirring screw is used to stir the developer inside the developing device, and the stirring screw is usually disposed along the developing roller to convey the developer in the longitudinal direction of the developing roller while stirring the developer. When the developer is conveyed using the stirring screw in this state, the low concentration portion of the developer is also moved as the spiral of the screw is moved, whereby uneven supply to the developing roller corresponding to the movement of the screw occurs. As a result, the influence of the uneven supply of the toner appears on formed images. Hence, in the conventional trickle developing device, the so-called screw irregularity phenomenon reflecting the uneven supply of the toner due to the use of the stirring screw occurs, and there is a problem of being unable to maintain high-quality images.

Accordingly, the technical problem to be solved by the present invention is to provide a developing device and an image forming apparatus capable of carrying out excellent image formation for a long period by making the fluctuations in the toner concentration and the volume level of the developer inside a trickle developing device that uses a two-component developer as small as possible.

SUMMARY OF THE INVENTION

To solve the above-mentioned technical problem, the present invention provides a developing device having stirring members for stirring a developer-tank-contained developer containing toner and carrier inside a developer tank while conveying the developer and a developer holder disposed adjacent to the stirring members to supply the stirred developer-tank-contained developer to an electrostatic latent image holder, comprising:

a developer replenishing tank for replenishing a replenishment developer containing the toner and the carrier to the developer tank,

a toner concentration detecting sensor for detecting the toner concentration inside the developer tank,

a discharging mechanism provided in the developer tank to discharge an excessive amount of the developer-tank-contained developer outside the developer tank when the amount of the developer-tank-contained developer inside the developer tank exceeds a predetermined amount, and

control unit for replenishing the replenishment developer when it is detected that the toner concentration inside the developer tank is lower than a first reference value and for forcibly consuming the toner inside the developer tank and replenishing the replenishment developer when it is detected that the toner concentration inside the developer tank is higher than a second reference value that is higher than the first reference value.

In the above-mentioned developing device, when it is detected that the toner concentration inside the developer tank is lower than the first reference value (that is, the first reference toner concentration), ordinary replenishment operation of replenishing the replenishment developer from the developer replenishing tank to the developer tank is carried out, whereby the toner concentration inside the developer tank rises. Furthermore, when it is detected that the toner concentration inside the developer tank is higher than the second reference value (that is, the second reference toner concentration), the operation of forcibly consuming the toner inside the developer tank is carried out, whereby the toner concentration inside the developer tank lowers, and the replenishing operation of the replenishment developer is carried out, whereby the lowered volume level inside the developer tank rises.

The replenishment amount of the replenishment developer at the time when it is detected that the toner concentration inside the developer tank is higher than the second reference value is made larger than the forced consumption amount of the toner inside the developer tank, whereby the lowered volume level inside the developer tank rises.

The operation of forcibly consuming the toner inside the developer tank is done by attaching the toner inside the developer tank to the electrostatic latent image holder. Since such a component incorporated in the image forming apparatus is used as described above, it not necessary to additionally install any toner consumption mechanism for forcibly consuming the toner, and the cost does not increase.

The control unit is characterized in that when it is detected that the toner concentration inside the developer tank is higher than the second reference value, the control unit carries out the operation of forcibly consuming the toner inside the developer tank until it is detected that the toner concentration inside the developer tank is lower than the first reference value and that after it is detected that the toner concentration inside the developer tank is lower than the first reference value, the control unit carries out the operation of forcibly consuming the toner inside the developer tank and the replenishment operation of the replenishment developer concurrently. With the above-mentioned control unit, the operation of forcibly consuming the toner inside the developer tank is carried out until it is detected that the toner concentration inside the developer tank is lower than the first reference value, whereby the toner concentration inside the developer tank lowers to the first reference value. After the toner concentration inside the developer tank becomes lower than the first reference value, the operation of forcibly consuming the toner inside the developer tank and the replenishment operation of the replenishment developer are carried out concurrently, whereby the lowered volume level inside the developer tank rises while the toner concentration inside the developer is maintained approximately at the first reference value. The invention set forth above corresponds to a first toner forced consumption mode described later.

The control unit is characterized in that when it is detected that the toner concentration inside the developer tank is higher than the second reference value, the control unit carries out the operation of forcibly consuming the toner inside the developer tank a predetermined number of times, and that the control unit carries out the operation of forcibly consuming the toner inside the developer tank and the replenishment operation of the replenishment developer concurrently a predetermined number of times, and then that the control unit carries out the operation of forcibly consuming the toner inside the developer tank until it is detected that the toner concentration inside the developer tank is lower than the second reference value. With the above-mentioned control unit, the operation of forcibly consuming the toner inside the developer tank is carried out the predetermined number of times, whereby the raised toner concentration inside the developer tank lowers to some extent. Furthermore, the operation of forcibly consuming the toner inside the developer tank and the replenishment operation of the replenishment developer are carried out the predetermined number of times in the state that the toner concentration inside the developer tank has lowered to some extent, whereby the volume level inside the developer tank gradually rises. Still further, the operation of forcibly consuming the toner inside the developer tank is carried out until the toner concentration inside the developer tank becomes lower than the second reference value, whereby the raised toner concentration lowers to the second reference value, and the volume level rises to a predetermined height. Hence, the replenishment developer is replenished at an early stage before the toner concentration inside the developer tank reaches the first reference value (that is, after the operation of forcibly consuming the toner is carried out the predetermined number of times), whereby the lowering of the toner concentration and the rising of the volume level inside the developer tank can be attained in shorter times. The invention set forth above corresponds to a second toner forced consumption mode described later.

The developing device is characterized in that the developing device further comprises a developer discharge detecting sensor for detecting whether the developer-tank-contained developer is discharged from the discharging mechanism and that when it is detected that the toner concentration inside the developer tank is higher than the second reference value, the control unit carries out the operation of forcibly consuming the toner inside the developer tank and the replenishment operation of the replenishment developer concurrently until the discharge of the developer-tank-contained developer is detected. With the above-mentioned developing device, the operation of forcibly consuming the toner and the replenishment operation of the replenishment developer are carried out concurrently until the discharge of the developer-tank-contained developer is actually detected using the developer discharge detecting sensor, whereby the volume level inside the developer tank gradually rises until the developer-tank-contained developer inside the developer tank is discharged using the discharging mechanism while the toner concentration is maintained at the first reference value. The invention set forth above corresponds to a third toner forced consumption mode described later.

The above-mentioned developing device is incorporated and used in an image forming apparatus comprising a rotatable electrostatic latent image holder for holding electrostatic latent images on the circumferential face thereof, stirring members for stirring a developer-tank-contained developer

containing toner and carrier inside a developer tank while conveying the developer, and a developer holder disposed adjacent to the stirring members to supply the stirred developer-tank-contained developer to the electrostatic latent image holder.

Since paper is wastefully consumed when ordinary image formation in which paper output is performed for the forced consumption operation of the toner inside the developer tank is carried out, the image forming apparatus further comprises transfer unit for transferring a toner image developed into a visible image using the developer holder onto paper from the circumferential face of the electrostatic latent image holder and cleaning device for removing nontransferred toner from the surface of the electrostatic latent image holder, whereby forcibly consumed toner is not transferred onto the paper but is recovered using the cleaning device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a view showing the schematic configuration of an image forming apparatus according to a first embodiment of the present invention;

FIG. **2** is a schematic sectional view showing the developing device of the image forming apparatus shown in FIG. **1** as seen from above;

FIG. **3** is a block diagram of the developing device of the image forming apparatus shown in FIG. **2**;

FIG. **4** is a flowchart of a subroutine regarding the replenishment operation of the developing device according to the first embodiment of the present invention;

FIG. **5** is a flowchart of a subroutine regarding a first toner forced consumption mode according to the first embodiment;

FIG. **6** is a flowchart of a subroutine regarding a second toner forced consumption mode according to a second embodiment;

FIG. **7** is a flowchart of a subroutine regarding a third toner forced consumption mode according to a third embodiment; and

FIG. **8** is a schematic sectional view showing part of the developing device of the image forming apparatus shown in FIG. **1** as seen from the side.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Preferred embodiments according to the present invention will be described below referring to the accompanying drawings. Although terms meaning specific directions (for example, "above," "below," "left" and "right" and other terms including these, and "clockwise" and "counterclockwise") are used in the following description, they are used for purposes of facilitating the understanding of the present invention referring to the drawings, and it should not be construed that the present invention is limited by the meanings of the terms. Furthermore, in an image forming apparatus **1** and a developing device **34** described below, identical or similar components are designated by the same reference numerals.

The image forming apparatus **1** and the developing device **34** incorporated therein according to a first embodiment of the present invention will be described referring to FIGS. **1** to **3**.

[Image Forming Apparatus]

FIG. **1** shows the components relating to image formation in the electrophotographic image forming apparatus **1** according to the present invention. The image forming apparatus **1** may be a copier, a printer, a facsimile machine or a compound machine combinedly equipped with the functions of these. The image forming apparatus **1** has a photosensitive member **12** serving as an electrostatic latent image holder. Although the photosensitive member **12** is formed of a cylinder in this embodiment, the photosensitive member **12** is not limited to have such a shape in the present invention, but it is possible to use an endless belt-type photosensitive member instead. The photosensitive member **12** is connected to a motor (not shown) so as to be driven and is rotated on the basis of the driving of the motor in the direction indicated by the arrow. Around the circumference of the photosensitive member **12**, a charging device **26**, an exposure device **28**, a developing device **34**, a transfer device **36** and a cleaning device **40** are respectively arranged along the rotation direction of the photosensitive member **12**.

The charging device **26** charges the photosensitive layer, that is, the outer circumferential face of the photosensitive member **12**, to a predetermined potential. Although the charging device **26** is represented as a cylindrical roller in this embodiment, instead of this, it is also possible to use charging devices of other forms (for example, a rotary or fixed brush type charging device and a wire discharging type charging device). The exposure device **28** disposed at a position close to or away from the photosensitive member **12** emits image light **30** toward the outer circumferential face of the charged photosensitive member **12**. An electrostatic latent image having an area wherein the image light **30** is projected and the charged potential is attenuated and an area wherein the charged potential is almost maintained is formed on the outer circumferential face of the photosensitive member **12** that has passed the exposure device **28**. In this embodiment, the area wherein the charged potential is attenuated is the image area of the electrostatic latent image, and the area wherein the charged potential is almost maintained is the non-image area of the electrostatic latent image. The developing device **34** develops the electrostatic latent image into a visible image using a developer-tank-contained developer **3** described later. The details of the developing device **34** are described later. The transfer device **36** transfers the visible image formed on the outer circumferential face of the photosensitive member **12** onto paper **38** or film. Although the transfer device **36** is shown as a cylindrical roller in the embodiment shown in FIG. **1**, it is also possible to use transfer devices having other forms (for example, a wire discharging type transfer device). The cleaning device **40** recovers non-transferred toner not transferred to the paper **38** by the transfer device **36** but remaining on the outer circumferential face of the photosensitive member **12** from the outer circumferential face of the photosensitive member **12**. Although the cleaning device **40** is shown as a plate-like blade in this embodiment, instead of this, it is also possible to use cleaning devices having other forms (for example, a rotary or fixed brush-type cleaning device).

When the image forming apparatus **1** configured as described above forms an image, the photosensitive member **12** is rotated counterclockwise, for example, on the basis of the driving of the motor (not shown). At this time, the outer circumferential area of the photosensitive member **12** passing the charging device **26** is charged to a predetermined potential at the charging device **26**. The outer circumferential area of the charged photosensitive member **12** is exposed to the image light **30** at the exposure device **28**, and an electrostatic latent image is formed. As the photosensitive member **12** is rotated, the electrostatic latent image is conveyed to the developing device **34** and developed into a visible image using the developing device **34**. As the photosensitive member **12** is rotated, the toner image developed into the visible image is conveyed to the transfer device **36** and transferred to the paper **38** using the transfer device **36**. The paper **38** to which the

toner image is transferred is conveyed to a fixing device **20**, and the toner image is fixed to the paper **38**. The outer circumferential area of the photosensitive member **12** having passed the transfer device **36** is conveyed to the cleaning device **40** in which the toner not transferred to the paper **38** but remaining on the outer circumferential face of the photosensitive member **12** is scraped off from the photosensitive member **12**.

[Developing Device]

The developing device **34** is provided with a two-component developer containing non-magnetic toner (hereafter simply referred to as toner) and magnetic carrier (hereafter simply referred to as carrier) and a developer tank **66** accommodating various members. The developer tank **66** has an opening section being open toward the photosensitive member **12**, and a developing roller **48** is installed in a space formed near the opening section. The developing roller **48** serving as a developer holder is a cylindrical member that is rotatably supported in parallel with the photosensitive member **12** while having a predetermined developing gap to the outer circumferential face of the photosensitive member **12**.

The developing roller **48** is the so-called magnetic roller having a magnet **48***a* secured so as not to be rotatable and a cylindrical sleeve **48***b* (first rotating cylinder) supported so as to be rotatable around the circumference of the magnet **48***a*. Above the sleeve **48***b* of the developing roller **48**, a regulating plate **62** secured to the developer tank **66** and extending in parallel with the center axis of the sleeve **48***b* of the developing roller **48** is disposed so as to be opposed thereto with a predetermined regulating gap therebetween. The magnet **48***a* disposed inside the developing roller **48** has five magnetic poles N**1**, S**2**, N**3**, N**2** and S**1** in the rotation direction of the sleeve **48***b*. Among these magnetic poles, the main magnetic pole N**1** is disposed so as to be opposed to the photosensitive member **12**. The magnetic poles N**2** and N**3** having the same polarity and generating a repulsive magnetic field for detaching the developer from the surface of the sleeve **48***b* are disposed so as to be opposed to each other inside the developer tank **66**. The sleeve **48***b* of the developing roller **48** rotates in the direction opposite to the rotation direction of the photosensitive member **12** (counter direction).

FIG. **2** is a schematic sectional view showing the developing device **34** as seen from above. As shown in FIG. **2**, a developer stirring and conveying chamber **67** is formed behind the developing roller **48**. The developer stirring and conveying chamber **67** comprises a second conveying passage **70** formed near the developing roller **48**, a first conveying passage **68** formed away from the developing roller **48** and a partition wall **76** for partitioning the space between the first conveying passage **68** and the second conveying passage **70**. Above the upstream side of the conveying direction of the first conveying passage **68**, a developer replenishing tank **80** is disposed and communicates with the first conveying passage **68** via a replenishing port **82**. The developer replenishing tank **80** is filled with a replenishment developer **2** containing toner as a major ingredient and carrier. The ratio of the carrier in the replenishment developer **2** is preferably 5 to 40 wt %, further preferably 10 to 30 wt %. In addition, below the downstream side of the conveying direction of the second conveying passage **70**, a developer recovery tank **90** is disposed and communicates with the second conveying passage **70** via a recovery port **92**.

At the bottom of the developer replenishing tank **80**, a developer supplying roller is disposed, the driving operation of which is controlled using a controller **100**. When the developer supplying roller is driven and rotated, the replenishment developer **2**, which is fresh and the amount of which corresponds to the driving time of the roller, flows downward and is supplied to the first conveying passage **68** of the developer tank **66**.

In the first conveying passage **68**, a first screw **72** serving as a stirring member for conveying the developer-tank-contained developer **3** while stirring the developer is rotatably supported. In the second conveying passage **70**, a second screw **74** for conveying the developer-tank-contained developer **3** from the first conveying passage **68** to the developing roller **48** while stirring the developer is rotatably supported. In this case, the upper portions of the partition wall **76** located at both end sections of the first conveying passage **68** and the second conveying passage **70** are cut out, and communicating passages are formed. The developer-tank-contained developer **3** having reached the end section on the downstream side in the conveying direction of the first conveying passage **68** is sent into the second conveying passage **70** via the communicating passage, and the developer-tank-contained developer **3** having reached the end section on the downstream side in the conveying direction of the second conveying passage **70** is sent into the first conveying passage **68** via the communicating passage. As a result, the developer-tank-contained developer **3** is circulated inside the developer stirring and conveying chamber in the direction indicated by the arrows shown in FIG. **2**.

The first screw **72** and the second screw **74** are each a spiral screw in which a spiral vane with a predetermined pitch is secured to a shaft. FIG. **8** is a schematic sectional view showing part of the developing device **34** as seen from the side and corresponding to the right end section shown in FIG. **2**. As shown in FIG. **8**, the second screw **74** is extended rightward in the figure and further extended above the recovery port **92**. At each of the positions corresponding to the communicating passage from the second conveying passage **70** to the first conveying passage **68** and to the downstream side end section of the first conveying passage **68**, the second screw **74** has a reverse vane section **77** in which the spiral direction of the spiral screw is opposite to that at the other section. The pitch of the vane of the second screw **74** at the downstream side end section (the right end section in FIG. **2**) in the conveying direction is made smaller than that at the other section. As a result, when the second screw **74** is rotated, the level of the developer-tank-contained developer **3** at the downstream side end section (the right end section) in the conveying direction of the second screw **74** becomes higher than that at the other vane section. In other words, a rising of the developer-tank-contained developer **3** is formed at the downstream side end section (the right end section) in the conveying direction of the second screw **74**.

Since the developing device **34** employs the so-called trickle system, the developing device has an outlet **75** for allowing an excessive amount of the developer-tank-contained developer **3** to flow out. In other words, the outlet **75** is formed by providing a cutout **75** that is formed by partially cutting out the upper portion of the side wall located at the downstream side end section (the right end section) in the conveying direction of the second conveying passage **70**. In a usual state, the developer being conveyed using the second screw **74** is stopped using the reverse vane section **77** and conveyed from the second conveying passage **70** to the first conveying passage **68** as indicated by the solid-line arrows shown in FIGS. **2** and **8**. When the developer-tank-contained developer **3** increases inside the developer tank and the developer level inside the developer tank rises, the developer-tank-contained developer **3** climbs over the outlet **75** disposed at the upper portion of the side wall against the damming action of the reverse vane section **77** and overflows to a recovery

chamber adjacent thereto. The excessive amount of the developer-tank-contained developer **3** overflowed to the recovery chamber is conveyed to the recovery port **92** in the directions indicated by the broken-line arrows shown in FIG. **8** and recovered (dumped) into the developer recovery tank **90** via the recovery port **92**.

In the developer stirring and conveying chamber **67**, a toner concentration detecting sensor **78** for detecting the toner concentration inside the developer stirring and conveying chamber **67** is provided. The toner concentration detecting sensor **78** detects the permeability of the developer-tank-contained developer **3** being conveyed inside the developer stirring and conveying chamber **67** on the basis of the change in the inductance of a coil, for example. The ratio of the toner in the developer-tank-contained developer **3** is obtained on the basis of the permeability detected using the toner concentration detecting sensor **78**. For example, when the amount of the carrier contained in the developer-tank-contained developer **3** is small, it is detected that the ratio of the toner is high. On the other hand, when the amount of the carrier contained in the developer-tank-contained developer **3** is large, it is detected that the ratio of the toner is low. In addition, the voltage signal output from the toner concentration detecting sensor **78** is input to the controller **100**, a required replenishing amount is calculated on the basis of the detection signal, the developer replenishing roller of the developer replenishing tank **80** is driven, and the predetermined amount of the replenishment developer **2** is replenished into the developer tank **66**.

In the developing device **34**, when the toner concentration of the circulating developer-tank-contained developer **3** lowers as the printing operation proceeds, the replenishment developer **2** containing toner and a small amount of carrier is replenished from the developer replenishing tank **80**. The replenishment developer **2** having been replenished is conveyed along the first conveying passage **68** and the second conveying passage **70** of the above-mentioned developer stirring and conveying chamber **67** while being mixed and stirred with the developer-tank-contained developer **3** already existing therein. Although the toner is basically consumed on the photosensitive member **12**, the carrier is accumulated inside the developing device **34**, and the charging performance of the carrier lowers gradually. Since a small amount of the carrier that is bulkier than the toner is contained in the replenishment developer **2**, as the replenishment developer **2** is replenished, the amount of the developer-tank-contained developer **3** gradually increases inside the developing device **34**. Then, the developer-tank-contained developer **3** having increased in volume circulates in the developer stirring and conveying chamber **67**. An excessive amount of the developer-tank-contained developer **3** being unable to circulate in the developer stirring and conveying chamber **67** climbs over the reverse vane section **77** and flows out from the outlet **75** provided at the downstream side end section (the right end section) in the conveying direction of the second conveying passage **70** and is recovered in the developer recovery tank **90** via the recovery port **92**. A developer discharge detecting sensor **112** is provided in the recovery port **92** or the developer stirring and conveying chamber **67**. The developer discharge detecting sensor **112** comprises, for example, a light-emitting device, such as an infrared LED, and a light-receiving device for receiving the light from the light-receiving device. The discharge of the excessive amount of the developer-tank-contained developer **3** is detected when the light-receiving device detects that the light from the light-emitting device is interrupted by the developer.

The replenishing amount of the replenishment developer **2** is determined on the basis of the toner concentration of the developer-tank-contained developer **3** detected using the toner concentration detecting sensor **78**, the image information (dot counter) at the time of image formation and the ratio of the carrier in the replenishment developer **2** inside the developer replenishing tank **80**. The ratio of the carrier in the replenishment developer **2** inside the developer replenishing tank **80** is adjusted to the extent that the carrier inside the developing device **34** is suppressed from deteriorating and that the cost is not increased. As the toner replenishing operation proceeds, the carrier is supplied gradually.

FIG. **3** is a control block diagram of the developing device **34** of the image forming apparatus **1**.

The controller **100** serving as control unit comprises a CPU (central processing unit) **102**, a ROM (read only memory) **104**, a RAM (random access memory) **106**, etc. The CPU **102** concentratedly controls various operations in the image forming apparatus **1** according to various processing programs and tables stored inside the ROM **104**. In the ROM **104**, for example, a toner concentration calculation table for carrying out calculation to convert the voltage detected using the toner concentration detecting sensor **78** into the toner concentration of the developer-tank-contained developer **3** and a developer replenishing table for calculating the amount of the developer to be replenished on the basis of the difference between the actual toner concentration of the developer-tank-contained developer **3** and the first reference toner concentration (that is, the first reference value). The RAM **106** provides a work area in which various programs to be executed by the controller **100** and data for the programs are temporarily stored.

The developing device **34**, the developer replenishing tank **80**, the developer discharge detecting sensor **112** and a counter **108** are connected to the controller **100**. The operations of the developer stirring members **72** and **74**, the toner concentration detecting sensor **78** and the developing roller **48** constituting the developing device **34** are controlled using the CPU **102** of the controller **100**. In addition, the toner concentration of the developer-tank-contained developer **3** detected using the toner concentration detecting sensor **78**, image information at the time of image formation, the ratio of the carrier in the replenishment developer **2** inside the developer replenishing tank **80**, etc. are temporarily stored in the RAM **106**.

[Developer]

The two-component developer contains toner and carrier for charging the toner. In the present invention, the known toner that has been used generally and conventionally can be used for the image forming apparatus **1**. The particle diameter of the toner is, for example, approximately 3 to 15 μm. It is also possible to use toner containing a coloring agent in a binder resin, toner containing a charge control agent and a releasing agent, and toner holding additives on the surface.

The toner is produced using known methods, such as the grinding method, the emulsion polymerization method and the suspension polymerization method.

Examples of the binder resin being used for the toner include styrene resins (homopolymers or copolymers containing styrene or styrene substitutes), polyester resins, epoxy resins, polyvinyl chloride resins, phenol resins, polyethylene resins, polypropylene resins, polyurethane resins, silicone resins or any appropriate combinations of these resins, although not restricted to these. The softening temperature of the binder resin is preferably in the range of approximately 80 to 160° C., and the glass transition temperature thereof is preferably in the range of approximately 50 to 75° C.

As the coloring agent, it is possible to use known materials, such as carbon black, aniline black, activated charcoal, magnetite, benzine yellow, permanent yellow, naphthol yellow,

phthalocyanine blue, fast sky blue, ultramarine blue, rose bengal and lake red. In general, the additive amount of the coloring agent is preferably 2 to 20 parts by weight per 100 parts by weight of the binder resin.

The materials conventionally known as charge control agents can be used as the charging control agent. More specifically, for the toner that is positively charged, it is possible to use materials, such as nigrosin dyes, quaternary ammonium salt compounds, triphenylmethane compounds, imidazole compounds and polyamine resins, as the charge control agent. For the toner that is negatively charged, it is possible to use materials, such as azo dyes containing metals such as Cr, Co, Al and Fe, salicylic acid metal compounds, alkyl salicylic acid metal compounds and calixarene compounds, as the charge control agent. It is desirable that the charge control agent is used in the ratio of 0.1 to 10 parts by weight per 100 parts by weight of the binder resin.

The materials conventionally known and used as releasing agents can be used as the releasing agent. As the material of the releasing agent, it is possible to use materials, such as polyethylene, polypropylene, carnauba wax, sasol wax or any appropriate combinations of these. It is desirable that the releasing agent is used in the ratio of 0.1 to 10 parts by weight per 100 parts by weight of the binder resin.

Furthermore, it may be possible to add a fluidizer for accelerating the fluidization of the developer. As the fluidizer, it is possible to use inorganic particles, such as silica, titanium oxide and aluminum oxide, and resin particles, such as acrylic resins, styrene resins, silicone resins and fluororesins. It is particularly desirable to use materials hydrophobized using a silane coupling agent, a titanium coupling agent, silicone oil, etc. It is desirable that the fluidizer is added in the ratio of 0.1 to 5 parts by weight per 100 parts by weight of the toner. It is desirable that the number average primary particle diameters of these additives are in the range of 9 to 100 nm.

As the carrier, the known carriers used conventionally and generally can be used. Either the binder-type carrier or the coated-type carrier may be used. It is desirable that the diameter of the carrier particles is in the range of approximately 15 to 100 μm, although not restricted to this range.

The binder-type carrier is that obtained by dispersing magnetic particles in a binder resin and it is possible to use carrier having positively or negatively charged particles or a coating layer on its surface. The charging characteristics, such as polarity, of the binder-type carrier can be controlled depending on the material of the binder resin, electrostatic charging particles and the kind of the surface coating layer.

Examples of the binder resin being used for the binder-type carrier include thermoplastic resins, such as vinyl resins typified by polystyrene resins, polyester resins, nylon resins and polyolefin resins, and thermosetting resins, such as phenol resins.

As the magnetic particles of the binder-type carrier, it is possible to use spinel ferrites, such as magnetite and gamma ferric oxide; spinel ferrites containing one or more kinds of nonferrous metals (such as Mn, Ni, Mg and Cu); magnetoplumbite ferrites, such as barium ferrite; and iron or alloy particles having oxide layers on the surfaces. The shape of the carrier may be particulate, spherical or needle-like. In particular, when high magnetization is required, it is desirable to use iron-based ferromagnetic particles. In consideration of chemical stability, it is desirable to use ferromagnetic particles of spinel ferrites, such as magnetite and gamma ferric oxide, or magnetoplumbite ferrites, such as barium ferrite. It is possible to obtain magnetic resin carrier having the desired magnetization by appropriately selecting the kind and content of the ferromagnetic particles. It is appropriate to add 50 to 90 wt % of the magnetic particles to the magnetic resin carrier.

As the surface coating material of the binder-type carrier, it is possible to use silicone resins, acrylic resins, epoxy resins, fluororesins, etc. The charging capability of the carrier can be enhanced by coating the surface of the carrier with this kind of resin and by thermosetting the resin.

The fixation of electrostatic charging particles or electrically conductive particles to the surface of the binder-type carrier is carried out according to, for example, a method in which the magnetic resin carrier is uniformly mixed with the particles, the particles are attached to the surface of the magnetic resin carrier, and then mechanical and thermal impact forces are applied to the particles to put the particles into the magnetic resin carrier. In this case, the particles are not completely embedded into the magnetic resin carrier but fixed such that parts thereof protrude from the surface of the magnetic resin carrier. As the electrostatic charging particles, organic or inorganic insulating materials are used. More specifically, as organic insulating materials, organic insulating particles, such as polystyrene, styrene copolymers, acrylic resins, various acrylic copolymers, nylon, polyethylene, polypropylene, fluororesins and cross-linked materials of these are available. The charging capability and the charging polarity thereof can be adjusted so as to be suited for the material of the electrostatic charging particles, polymerization catalyst, surface treatment, etc. As the inorganic insulating material, negatively charged inorganic particles, such as silica and titanium dioxide, and positively charged inorganic particles, such as strontium titanate and alumina, are used.

The coated-type carrier is carrier obtained by coating carrier core particles made of a magnetic substance with a resin, and electrostatic charging particles charged positively or negatively can be fixed to the surface of the carrier, as in the case of the binder-type carrier. The charging characteristics, such as polarity, of the coated-type carrier can be adjusted by selecting the kind of the surface coating layer and the electrostatic charging particles. As the coating resin, it is possible to use resins similar to the binder resins for the binder-type carrier.

The mixture ratio of the toner and the carrier of the developer-tank-contained developer **3** is adjusted such that a desired toner charging amount is obtained. The ratio of the toner in the developer-tank-contained developer **3** is preferably 3 to 20 wt % and further preferably 4 to 15 wt % with respect to the total amount of the toner and the carrier. In addition, the replenishment developer **2** stored in the developer replenishing tank **80** contains toner and a small amount of carrier, and the ratio of the carrier in the replenishment developer **2** is preferably 1 to 50 wt % and further preferably 5 to 30 wt %.

The operation of the developing device **34** configured as described above will be described.

At the time of image formation, the sleeve **48***b* of the developing roller **48** is rotated in the direction indicated by the arrow (counterclockwise) on the basis of the driving of the motor (not shown). By the rotation of the first screw **72** and the rotation of the second screw **74**, the developer-tank-contained developer **3** existing in the developer stirring and conveying chamber **67** is stirred while being circulated and conveyed between the first conveying passage **68** and the second conveying passage **70**. As a result, the toner and the carrier contained in the developer make friction contact and are charged to have polarities opposite to each other. In this embodiment, it is assumed that the carrier is positively charged and that the toner is negatively charged. However, the charging characteristics of the toner and the carrier being used

for the present invention are not limited to these combinations. The external size of the carrier is considerably larger than that of the toner. For this reason, the negatively charged toner is attached around the circumference of the positively charged carrier mainly on the basis of the electric attraction force exerted therebetween.

The developer-tank-contained developer **3** charged as described above is supplied to the developing roller **48** in the process of being conveyed to the second conveying passage **70** using the second screw **74**. The developer is held on the surface of the sleeve **48***b* by the magnetic force of the magnet **48***a* inside the developing roller **48** and moved while being rotated counterclockwise together with the sleeve **48***b*, the throughput thereof is regulated using the regulating plate **62** disposed so as to be opposed to the developing roller **48**, and then the developer is conveyed to the developing area opposed to the photosensitive member **12**. Furthermore, in the developing area, chains of particles (magnetic brush) are formed by the magnetic force of the main magnet pole N**1** of the magnet **48***a*. In the developing area, by the force of the electric field (electric field of AC superimposed on DC) that is formed between the electrostatic latent image on the photosensitive member **12** and the developing roller **48** to which a developing bias is applied and exerted to the toner, the toner is moved to the electrostatic latent image on the photosensitive member **12**, and the electrostatic latent image is developed into a visible image. The developer, the toner of which is consumed in the developing area, is conveyed toward the developer tank **66**, detached from the surface of the developing roller **48** by the repulsive magnetic field between the poles N**3** and N**2** of the magnet **48***a* disposed so as to be opposed to the second conveying passage **70** of the developer tank **66**, and then recovered into the developer tank **66**. The recovered developer is mixed with the developer-tank-contained developer **3** that is being conveyed to the second conveying passage **70**.

When the toner contained in the developer-tank-contained developer **3** is forcibly consumed by the image formation described above, it is desirable that the amount of the toner corresponding to the consumed amount is replenished to the developer-tank-contained developer **3**. For this purpose, the developing device **34** is equipped with the toner concentration detecting sensor **78** for measuring the ratio of the toner in the developer-tank-contained developer **3** existing in the developer stirring and conveying chamber **67**. Furthermore, the developer replenishing tank **80** is provided above the first conveying passage **68**.

The image formation according to the present invention is broadly classified into ordinary image formation in which paper output is performed after development and the so-called patch image formation in which paper output is not performed after development. The patch image formation means image formation in which an electrostatic latent image in a solid state is formed on the photosensitive member **12** by keeping the radiation state of the image light **30** of the exposure device **28** at a predetermined amount of light without switching the image light **30** of the exposure device **28** between the radiation and nonradiation state on the basis of image data. By the development of the electrostatic latent image in the solid state, toner is forcibly attached onto the photosensitive member **12**, and the forcibly attached toner is recovered using the cleaning device **40** without being transferred onto the paper **38**, whereby the toner is forcibly consumed. Since the paper **38** is wastefully consumed if ordinary image formation is carried out for the forced consumption of toner, patch image formation is used for the forced consumption of toner in the present invention. Furthermore, for the purpose that toner is consumed as much as possible by one patch image formation operation at the time of the forced consumption of toner, it is desirable that the area of the photosensitive member **12** radiated with the image light **30** is as wide as possible in the patch image formation.

Next, the operation of the developing device **34** according to the first embodiment will be described referring to FIGS. **4** and **5**.

FIG. **4** is a main flowchart showing the replenishment operation for the developing device **34** according to the first embodiment of the present invention. FIG. **5** is a flowchart in a first toner forced consumption mode according to the first embodiment. Although the description is given while the following specific numeric values are used to facilitate the understanding of the first toner forced consumption mode according to the first embodiment, the numeric values are only examples, and this embodiment is not restricted by the numeric values.

The first reference toner concentration (that is, the first reference value) of the developer-tank-contained developer **3** stored in the trickle developing device **34** is 7 wt %, and its amount is approximately 250 g. When it is assumed that the second reference toner concentration (that is, the second reference value) of the developer-tank-contained developer **3** inside the developing device **34** is the first reference toner forced consumption (7 wt %)+2 wt %, the second reference toner concentration is 9 wt %. The amount of the developer stored inside the developing device **34** at the second reference toner concentration (9 wt %) is approximately 210 g. The amount of the toner to be consumed by one patch image formation operation is approximately 0.5 g. The ratio of the carrier in the replenishment developer **2** is 15 wt %. The replenishment amount of the replenishment developer **2** in one replenishment operation is approximately 0.6 g, corresponding to approximately 0.5 g when converted into the amount of the toner. The number K of replenishment operations for the replenishment developer **2** is 100.

FIG. **4** shows a subroutine regarding the replenishment control for the developing device **34** in the entire control (main routine), not shown. At step S**12**, a voltage signal regarding the toner concentration of the developer-tank-contained developer **3** existing in the developer stirring and conveying chamber **67** is output from the toner concentration detecting sensor **78**. At step S**14**, the output voltage signal is converted by calculation into the value of the toner concentration using the controller **100**. At step S**20**, a judgment is made as to whether the current toner concentration is lower than the first reference toner concentration (7 wt %). When the current toner concentration is judged to be lower than the first reference toner concentration, at step S**22**, the replenishment amount of the replenishment developer **2** is calculated on the basis of the current toner concentration detected using the toner concentration detecting sensor **78**, the image information (dot counter) at the time of image formation and the ratio of the carrier in the replenishment developer **2** inside the developer replenishing tank **80**. Furthermore, at step S**24**, the predetermined amount of the replenishment developer **2** is replenished and the process returns to step S**12** for toner concentration detection.

When the current toner concentration is judged to be equal to or higher than the first reference toner concentration at step S**20**, a judgment is made at step S**30** as to whether the current toner concentration is lower than the second reference toner concentration (9 wt %). When the current toner concentration is judged to be lower than the second reference toner concentration (9 wt %), the subroutine ends, and the process returns to the main routine. When the current toner concentration is

judged to be equal to or higher than the second reference toner concentration (9 wt %) due to the measurement accuracy of the toner concentration detecting sensor **78**, the filling state of the developer-tank-contained developer **3** around the toner concentration detecting sensor **78** and the changes in the ambient environment of the image forming apparatus, the process shifts to the first toner forced consumption mode at step S**40**. At this time, the amount of the developer-tank-contained developer **3** stored inside the developing device **34** is approximately 210 g.

FIG. **5** shows a subroutine regarding the first toner forced consumption mode of the subroutine regarding the replenishment control for the developing device **34**, shown in FIG. **4**. At step S**112**, the number K (100) of replenishment operations, that is, the number of how many times the replenishment developer **2** is replenished is set. At step S**114**, patch image formation in which paper output is not performed after development is carried out for toner forced consumption operation. In this patch image formation, for the purpose that toner is consumed as much as possible by one patch image formation operation, an image is formed in a solid state so as to cover the almost entire face. Approximately 0.5 g of toner is consumed by one patch image formation operation.

When it is judged that the replenishment is not carried out predetermined number of times (100), at step S**124**, a voltage signal regarding the toner concentration of the developer-tank-contained developer **3** existing in the developer stirring and conveying chamber **67** is output from the toner concentration detecting sensor **78**. At step S**126**, the output voltage signal is converted by calculation into the value of the toner concentration using the controller **100**. At step S**130**, a judgment is made as to whether the detected current toner concentration of the developer-tank-contained developer **3** is lower than the first reference toner concentration (7 wt %).

At step S**130**, when the current toner concentration of the developer-tank-contained developer **3** is judged to be equal to or higher than the first reference toner concentration (7 wt %), the process returns to step S**114** for patch image formation. In other words, the patch image formation at step S**114** is repeated until the current toner concentration becomes lower than the first reference toner concentration (7 wt %). For example, patch image formation is repeated a dozen of times. Since patch image formation is repeated, the toner is consumed, and the toner concentration gradually lowers; however, since the replenishment of the replenishment developer **2** is not carried out, the volume level of the developer-tank-contained developer **3** inside the developer tank **55** lowers.

When it is judged at step S**130** that the current toner concentration of the developer-tank-contained developer **3** has become lower than the first reference toner concentration (7 wt %), that is, when it is judged that the current toner concentration of the developer-tank-contained developer **3** is restored to the first reference toner concentration as the result of the repetition of the patch image formation, the replenishment amount of the replenishment developer **2** is calculated at step S**132** on the basis of the current toner concentration of the developer-tank-contained developer **3** detected using the toner concentration detecting sensor **78**, the image information (dot counter) at the time of image formation and the ratio of the carrier in the replenishment developer **2** inside the developer replenishing tank **80**. Furthermore, at step S**134**, the calculated amount (approximately 0.6 g) of the replenishment developer **2** is replenished, and the number of repetitions of the routine is decreased by one, and the process returns to step S**114** for patch image formation. Although the toner is consumed by the patch image formation at step S**114**, since the replenishment amount (approximately 0.5 g) of the toner is balanced with the consumed amount (approximately 0.5 g), the toner concentration of the developer-tank-contained developer **3** is maintained in the restored state, that is, the first reference toner concentration (7 wt %). As a result, the process goes to YES wherein the judgment at step S**130** is made such that the current toner concentration of the developer-tank-contained developer **3** has become substantially lower than the first reference toner concentration (7 wt %). Hence, in addition to the toner consumption operation by the patch image formation at step S**114**, the replenishment operation of the replenishment developer **2** from step S**134** to S**136** is repeated. This means that the carrier contained in the replenishment developer **2** is being replenished while the current toner concentration of the developer-tank-contained developer **3** is being restored to the first reference toner concentration (7 wt %), in other words, the volume level of the developer-tank-contained developer **3** inside the developer tank **66** rises gradually as the carrier is replenished.

At step S**120**, a judgment is made as to whether replenishment is carried out the predetermined number of times (100). When it is judged that replenishment is carried out the predetermined number of times (100), the subroutine regarding the first toner forced consumption mode ends, and the process returns to the subroutine regarding the replenishment control for the developing device **34**, shown in FIG. **4**.

In the first toner forced consumption mode, during the replenishment operation of the replenishment developer **2**, the accuracy in the toner concentration and the volume level of the developer-tank-contained developer **3** is well balanced with the time required for the replenishment.

When general image formation was carried out using the image forming apparatus **1** having the first toner forced consumption mode described above, image loss due to screw irregularity or the like did not occur, and the effect of the first toner forced consumption mode has been verified.

Next, the operation of the developing device **34** according to a second embodiment will be described referring to FIG. **6**.

FIG. **6** is a flowchart of a subroutine regarding a second toner forced consumption mode according to the second embodiment. Although the description is given while the following specific numeric values are used to facilitate the understanding of the second toner forced consumption mode according to the second embodiment, the numeric values are only examples, and this embodiment is not restricted by the numeric values.

The first reference toner concentration of the developer-tank-contained developer **3** stored in the trickle developing device **34** is 7 wt %, and its amount is approximately 250 g. When it is assumed that the second reference toner concentration of the developer-tank-contained developer **3** inside the developing device **34** is the first reference toner forced consumption (7 wt %)+2 wt %, the second reference toner concentration is 9 wt %. The amount of the developer stored inside the developing device **34** at the second reference toner concentration (9 wt %) is approximately 210 g. The amount of toner to be consumed by one patch image formation operation is approximately 0.5 g. The ratio of the carrier in the replenishment developer **2** is 15 wt %. The replenishment amount of the replenishment developer **2** is approximately 0.6 g in one replenishment operation, corresponding to approximately 0.5 g when converted into the amount of the toner. The number M of image formation operations is 100. The number L of times before the start of replenishment is 5.

In the second embodiment, since the subroutine regarding the replenishment control for the developing device **34** is the same as that for the above-mentioned first embodiment, the description thereof is omitted, and only the subroutine regard-

ing the second toner forced consumption mode, different from that of the first embodiment, will be described.

FIG. **6** shows a subroutine regarding the second toner forced consumption mode of the subroutine regarding the replenishment control for the developing device **34**, shown in FIG. **4**. At step S**212**, the number M (100) of image formation operations, that is, the number of how many times image formation operation is carried out, is set; furthermore, the number L (for example, 5) of times before the start of replenishment, that is, the number of how many times image formation is carried out before the start of replenishment, is set. At step S**214**, patch image formation in which paper output is not performed after development is carried out for toner forced consumption operation. In this patch image formation, for the purpose that toner is consumed as much as possible by one patch image formation operation, an image is formed in a solid state so as to cover the almost entire face. Approximately 0.5 g of toner is consumed by one patch image formation operation. At step S**220**, a judgment is made as to whether image formation is carried out the number of predetermined times (100).

When it is judged at step S**220** that image formation is not carried out the predetermined number of times (100), the process advances to step S**240**, image formation is carried out a predetermined number of times, and a judgment is made as to whether the number of predetermined times has reached the predetermined number of times before the start of replenishment (100−5=95). When it is judged at step S**240** that the number of predetermined times has not reached the predetermined number of times before the start of replenishment, the number of repetitions of the routine is decreased by one, and the process returns to step S**214** for patch image formation. According to the setting condition described above, since the number of times before the start of replenishment is reached after image formation is repeated 5 times, it is judged at step S**240** that the predetermined number of times before the start of replenishment has been reached.

When it is judged at step S**240** that the predetermined number of times before the start of replenishment has been repeated, the predetermined amount (approximately 0.6 g) of the replenishment developer **2** is replenished. Then, at step S**244**, the number of repetitions of the routine is decreased by one, and the process returns to step S**214** for patch image formation. Although the toner is consumed by the patch image formation at step S**214**, since the replenishment amount (approximately 0.5 g) of the toner is balanced with the consumed amount (approximately 0.5 g), the toner concentration of the developer-tank-contained developer **3** is maintained in a state decreased by the amount approximately corresponding to the five times of image formation operations.

After image formation is carried out 100 times in total, it is judged at step S**220** that image formation has been carried out the predetermined number of times, and at step S**222**, a voltage signal regarding the toner concentration of the developer-tank-contained developer **3** existing in the developer stirring and conveying chamber **67** is output from the toner concentration detecting sensor **78**. At step S**224**, the output voltage signal is converted by calculation into the value of the toner concentration of the developer-tank-contained developer **3** using the controller **100**. At step S**230**, a judgment is made as to whether the detected current toner concentration of the developer-tank-contained developer **3** is lower than the second reference toner concentration (9 wt %).

At step S**230**, when the current toner concentration of the developer-tank-contained developer **3** is judged to be equal to or higher than the second reference toner concentration (9 wt %), the process returns to step S**214** for patch image formation. In other words, the patch image formation at step S**214** is repeated until the current toner concentration of the developer-tank-contained developer **3** becomes lower than the second reference toner concentration (9 wt %). Since patch image formation is repeated, toner is consumed, and the toner concentration of the developer-tank-contained developer **3** gradually lowers; however, since the replenishment of the replenishment developer **2** is not carried out, the volume level of the developer-tank-contained developer **3** inside the developer tank **55** lowers.

When it is judged at step S**230** that the current toner concentration of the developer-tank-contained developer **3** is lower than the second reference toner concentration (9 wt %), the subroutine regarding the second toner forced consumption mode ends, and the process returns to the subroutine regarding the replenishment control for the developing device **34**, shown in FIG. **4**.

In the second toner forced consumption mode, since the toner concentration of the developer-tank-contained developer **3** is stipulated by the second reference toner concentration and the volume level of the developer-tank-contained developer **3** is stipulated by the number of times before the start of replenishment, it is characterized in that the time required for the replenishment of the replenishment developer **2** can be reduced remarkably although the accuracy in the toner concentration and the volume level of the developer-tank-contained developer **3** becomes low.

When general image formation was carried out using the image forming apparatus **1** having the second toner forced consumption mode described above, image loss due to screw irregularity or the like did not occur, and the effect of the second toner forced consumption mode has been verified.

Next, the operation of the developing device **34** according to a third embodiment will be described referring to FIG. **7**.

A FIG. **7** is a flowchart of a subroutine regarding a third toner forced consumption mode according to the third embodiment. Although the description is given while the following specific numeric values are used to facilitate the understanding of the third toner forced consumption mode according to the third embodiment, the numeric values are only examples, and this embodiment is not restricted by the numeric values.

The first reference toner concentration of the developer-tank-contained developer **3** stored in the trickle developing device **34** is 7 wt %, and its storage amount is approximately 250 g. When it is assumed that the second reference toner concentration of the developer-tank-contained developer **3** inside the developing device **34** is the first reference toner forced consumption (7 wt %)+2 wt %, the second reference toner concentration is 9 wt %. The amount of the developer-tank-contained developer **3** stored inside the developing device **34** at the second reference toner concentration (9 wt %) is approximately 210 g. The amount of the toner to be consumed by one patch image formation operation is approximately 0.5 g. The ratio of the carrier in the replenishment developer **2** is 15 wt %. The replenishment amount of the replenishment developer **2** is approximately 0.6 g in one replenishment operation, corresponding to approximately 0.5 g when converted into the amount of the toner.

In the third embodiment, since the subroutine regarding the replenishment control for the developing device **34** is the same as that of the above-mentioned first embodiment, the description thereof is omitted, and only the subroutine regarding the third replenishment control correction mode, different from that of the first embodiment, will be described.

FIG. **7** shows a subroutine regarding the third toner forced consumption mode of the subroutine regarding the replenishment control for the developing device **34**, shown in FIG. **4**. At step S**312**, patch image formation in which paper output is not performed after development is carried out for toner forced consumption operation. In this patch image formation, for the purpose that toner is consumed as much as possible by one patch image formation operation, an image is formed in a solid state so as to cover the almost entire face. Approximately 0.5 g of toner is consumed by one patch image formation operation.

At step S**314**, a voltage signal regarding the toner concentration of the developer-tank-contained developer **3** existing in the developer stirring and conveying chamber **67** is output from the toner concentration detecting sensor **78**. At step S**316**, the output voltage signal is converted by calculation into the value of the toner concentration of the developer-tank-contained developer **3** using the controller **100**. At step S**320**, a judgment is made as to whether the detected current toner concentration of the developer-tank-contained developer **3** is lower than the first reference toner concentration (7 wt %).

At step S**330**, when the current toner concentration of the developer-tank-contained developer **3** is judged to be equal to or higher than the first reference toner concentration (7 wt %), the process returns to step S**312** for patch image formation. In other words, the patch image formation at step S**312** is repeated until the current toner concentration of the developer-tank-contained developer **3** becomes lower than the first reference toner concentration (7 wt %). Since patch image formation is repeated, the toner is consumed, and the toner concentration of the developer-tank-contained developer **3** gradually lowers; however, since the replenishment of the replenishment developer **2** is not carried out, the volume level of the developer-tank-contained developer **3** inside the developer tank **55** lowers.

When it is judged at step S**320** that the current toner concentration of the developer-tank-contained developer **3** has become lower than the first reference toner concentration (7 wt %), that is, when it is judged that the current toner concentration of the developer-tank-contained developer **3** is restored to the first reference toner concentration as the result of the repetition of the patch image formation, the replenishment amount of the replenishment developer **2** is calculated at step S**322** on the basis of the current toner concentration of the developer-tank-contained developer **3**. Furthermore, at step S**324**, the predetermined amount (approximately 0.6 g) of the replenishment developer **2** is replenished, and at step S**330**, a judgment is made as to whether the developer-tank-contained developer **3** has been discharged into the developer recovery tank **90**.

When it is judged at step S**330** that the developer-tank-contained developer **3** has not been discharged into the developer recovery tank **90**, the process returns to step S**312** for patch image formation.

Although the toner is consumed by the patch image formation at step S**312**, since the replenishment amount (approximately 0.5 g) of the toner is balanced with the consumed amount (approximately 0.5 g), the toner concentration of the developer-tank-contained developer **3** is maintained at the restored value, that is, the first reference toner concentration (7 wt %). As a result, the process goes to YES wherein the judgment at step S**320** is made such that the current toner concentration of the developer-tank-contained developer **3** has become substantially lower than the first reference toner concentration (7 wt %). Hence, in addition to the toner consumption operation by the patch image formation at step S**312**, the replenishment operation of the replenishment developer **2** from step S**322** to S**330** and the discharge detection of the developer-tank-contained developer **3** are repeated. This means that the replenishment developer **2**, that is, the carrier, is being replenished while the current toner concentration of the developer-tank-contained developer **3** is being restored to the first reference toner concentration (7 wt %), in other words, the volume level of the developer-tank-contained developer **3** inside the developer tank **66** rises gradually as the carrier is replenished.

When it is judged at step S**330** that the developer-tank-contained developer **3** has been discharged into the developer recovery tank **90**, this means that the developer-tank-contained developer **3** inside the developer stirring and conveying chamber **67** flows out from the outlet and actually drops into the developer recovery tank **90** and that the volume level of the developer-tank-contained developer **3** has been restored to the reference volume level; hence, the third toner forced consumption mode ends at step S**332**.

In the third toner forced consumption mode, the toner concentration and the volume level of the developer-tank-contained developer **3** can be restored accurately to the predetermined values by the replenishment operation of the replenishment developer **2**. In the third toner forced consumption mode, the replenishment developer **2** is replenished until the volume level of the developer-tank-contained developer **3** is restored to the predetermined volume level, and a large amount of the replenishment developer **2** is required; hence, the mode is ideally suited in the case that the developer tank **66** of the developing device **34** is small in size.

When general image formation was carried out using the image forming apparatus **1** having the third toner forced consumption mode described above, image loss due to screw irregularity or the like did not occur, and the effect of the third toner forced consumption mode has been verified.

Although the description is given using specific numeric values in the above-mentioned respective embodiments, the present invention is not restricted by the numeric values but can be modified variously without departing from the scope defined in the appended claims and equivalents thereof.

What is claimed is:

1. A developing device having stirring members for stirring a developer-tank-contained developer containing toner and carrier inside a developer tank while conveying the developer and a developer holder disposed adjacent to said stirring members to supply the stirred developer-tank-contained developer to an electrostatic latent image holder, comprising:

a developer replenishing tank for replenishing a replenishment developer containing the toner and the carrier to said developer tank,

a toner concentration detecting sensor for detecting the toner concentration inside said developer tank,

a discharging mechanism provided in said developer tank to discharge an excessive amount of the developer-tank-contained developer outside said developer tank when the amount of the developer-tank-contained developer inside said developer tank exceeds a predetermined amount, and

control unit for replenishing the replenishment developer when it is detected that the toner concentration inside said developer tank is lower than a first reference value and for forcibly consuming the toner inside said developer tank and replenishing the replenishment developer when it is detected that the toner concentration inside said developer tank is higher than a second reference value that is higher than said first reference value.

2. The developing device according to claim 1, wherein the replenishment amount of the replenishment developer at the time when it is detected that the toner concentration inside said developer tank is higher than said second reference value is made larger than the forced consumption amount of the toner inside said developer tank.

3. The developing device according to claim 2, wherein when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank until it is detected that the toner concentration inside said developer tank is lower than said first reference value, and after it is detected that the toner concentration inside said developer tank is lower than said first reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently.

4. The developing device according to claim 2, wherein when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank a predetermined number of times, and said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently a predetermined number of times, and then said control unit carries out the operation of forcibly consuming the toner inside said developer tank until it is detected that the toner concentration inside said developer tank is lower than said second reference value.

5. The developing device according to claim 2, wherein

said developing device further comprises a developer discharge detecting sensor for detecting whether the developer-tank-contained developer is discharged from said discharging mechanism, and

when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently until the discharge of the developer-tank-contained developer is detected.

6. The developing device according to claim 1, wherein the operation of forcibly consuming the toner inside said developer tank is done by attaching the toner inside said developer tank to said electrostatic latent image holder.

7. The developing device according to claim 6, wherein when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank until it is detected that the toner concentration inside said developer tank is lower than said first reference value, and after it is detected that the toner concentration inside said developer tank is lower than said first reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently.

8. The developing device according to claim 6, wherein when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank a predetermined number of times, and said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently a predetermined number of times, and then said control unit carries out the operation of forcibly consuming the toner inside said developer tank until it is detected that the toner concentration inside said developer tank is lower than said second reference value.

9. The developing device according to claim 6, wherein

said developing device further comprises a developer discharge detecting sensor for detecting whether the developer-tank-contained developer is discharged from said discharging mechanism, and

when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently until the discharge of the developer-tank-contained developer is detected.

10. The developing device according to claim 1, wherein when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank until it is detected that the toner concentration inside said developer tank is lower than said first reference value, and after it is detected that the toner concentration inside said developer tank is lower than said first reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently.

11. The developing device according to claim 1, wherein when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank a predetermined number of times, and said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently a predetermined number of times, and then said control unit carries out the operation of forcibly consuming the toner inside said developer tank until it is detected that the toner concentration inside said developer tank is lower than said second reference value.

12. The developing device according to claim 1, wherein

said developing device further comprises a developer discharge detecting sensor for detecting whether the developer-tank-contained developer is discharged from said discharging mechanism, and

when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently until the discharge of the developer-tank-contained developer is detected.

13. An image forming apparatus having a rotatable electrostatic latent image holder for holding electrostatic latent images on the circumferential face thereof, stirring members for stirring a developer-tank-contained developer containing toner and carrier inside a developer tank while conveying said developer, and a developer holder disposed adjacent to said stirring members to supply the stirred developer-tank-contained developer to said electrostatic latent image holder, comprising:

a developer replenishing tank for replenishing a replenishment developer containing the toner and the carrier to said developer tank,

a toner concentration detecting sensor for detecting the toner concentration inside said developer tank,

a discharging mechanism provided in said developer tank to discharge an excessive amount of the developer-tank-contained developer outside said developer tank when the amount of the developer-tank-contained developer inside said developer tank exceeds a predetermined amount, and

control unit for replenishing the developer-tank-contained developer when it is detected that the toner concentration inside said developer tank is lower than a first reference value and for forcibly consuming the toner inside said developer tank and replenishing the replenishment developer when it is detected that the toner concentration inside said developer tank is higher than a second reference value that is higher than said first reference value.

14. The image forming apparatus according to claim **13**, further comprising transfer unit for transferring a toner image developed into a visible image using said developer holder onto paper from the circumferential face of said electrostatic latent image holder and a cleaning device for removing non-transferred toner from the surface of said electrostatic latent image holder, wherein

forcibly consumed toner is not transferred onto the paper but is recovered using said cleaning device.

15. The image forming apparatus according to claim **14**, wherein when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank until it is detected that the toner concentration inside said developer tank is lower than said first reference value, and after it is detected that the toner concentration inside said developer tank is lower than said first reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently.

16. The image forming apparatus according to claim **14**, wherein when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank a predetermined number of times, and said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently a predetermined number of times, and then said control unit carries out the operation of forcibly consuming the toner inside said developer tank until it is detected that the toner concentration inside said developer tank is lower than said second reference value.

17. The image forming apparatus according to claim **14**, wherein

said image forming apparatus further comprises a developer discharge detecting sensor for detecting whether the developer-tank-contained developer is discharged from said discharging mechanism, and

when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently until the discharge of the developer-tank-contained developer is detected.

18. The image forming apparatus according to claim **13**, wherein when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank until it is detected that the toner concentration inside said developer tank is lower than said first reference value, and after it is detected that the toner concentration inside said developer tank is lower than said first reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently.

19. The image forming apparatus according to claim **13**, wherein when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank a predetermined number of times, and said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently a predetermined number of times, and then said control unit carries out the operation of forcibly consuming the toner inside said developer tank until it is detected that the toner concentration inside said developer tank is lower than said second reference value.

20. The image forming apparatus according to claim **13**, wherein

said image forming apparatus further comprises a developer discharge detecting sensor for detecting whether the developer-tank-contained developer is discharged from said discharging mechanism, and

when it is detected that the toner concentration inside said developer tank is higher than said second reference value, said control unit carries out the operation of forcibly consuming the toner inside said developer tank and the replenishment operation of the replenishment developer concurrently until the discharge of the developer-tank-contained developer is detected.

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